AOS 580 Aerosol, Cloud, Climate Change

MIDTERM: Lecture 1-11; due by Thursday March 27, 2008

1. Explain in one or two sentences whether you ***agree*** or ***disagree*** with each statement below. Support your position with equations or calculations when appropriate. Address any 10 of the 12 statements (only the first 10 will be graded).

   1. For two aerosols with the same mass concentration, surface area will be higher for the aerosol with smaller particles.

   This statement is true. For the same mass concentration, surface area is proportional to 1/d where d is diameter.

   2. The number, surface and volume log-normal distribution of one sample of particles have the same geometric standard deviation.

   This statement is true. This is a property of log-normal distribution.

   3. The geometric mean diameter is smaller than the volume median diameter for a lognormal distribution.

   This statement is true. $D_V = D_{pg} \exp(3\ln^2 \sigma_g)$ and because $\sigma_g > 0$ then $D_V > D_{pg}$

   4. Gravitational settling is not very important for spherical particles of 1 μm in diameter compare to wind speed.

   This statement is true. $v_d = \dfrac{\rho g d^2}{18\mu} \approx \dfrac{10^3 kg.m^{-3} \times 10 m.s^{-2} \times 10^{-12} m^2}{20 \times 10^{-5} kg.m^{-1} s^{-1}} = 5 \times 10^{-5} m.s^{-1}$ while the vertical wind velocity is of the order of 10^{-2} $m.s^{-1}$

   5. Submicron particles are particularly important if we are concerned about diseases of the deep lung.

   This statement is true. The submicron particles reach deep into the lungs, where they are very difficult to be removed.

   6. Dust single scattering albedo decreases with increase amount of hematite.

   This statement is true. Hematite is strongly absorbing compare to allumino-sillicates forming the matrix of dust aerosols (mostly clay and silt). As the single scattering albedo is proportional to the amount of scattering in the total extinction (scattering+absorption), it will decrease as the absorption increases.

   7. For spherical particles, the Mie theory can be used for any aerosol size and at any wavelength of the solar spectrum.

   This statement is true. In contrast to Rayleigh scattering and geometric optic, the Mie solution to the scattering problem is valid for all possible ratios of diameter to wavelength.

8. The sky is blue because of the wavelength dependency of Rayleigh scattering

This statement is true. Rayleigh scattering: $Q_{scat} \approx \lambda^{-4}$ and blue $\lambda = 440\,\text{nm}$ is the lowest wavelength of the visible spectrum.

9. The single scattering albedo decreases with increasing absorption

This statement is true. $\omega = \dfrac{\varepsilon_{scat}}{\varepsilon_{scat} + \varepsilon_{abs}}$. If ε_{abs} increases, then ω decreases.

10. One optical thickness corresponds to an attenuation of light intensity of a factor of 1, 2, 3, or 10 (pick-up the closest).

The correct answer is 3. $I = I_0 \exp(-\tau) = I_0 \exp(-1) \approx \dfrac{I_0}{3}$

11. Angstrom exponent can be used to estimate the optical thickness at any wavelength from two known values of optical thickness at 2 wavelengths.

This statement is true. $\alpha = -\dfrac{\log(\tau_1/\tau_2)}{\log(\lambda_1/\lambda_2)}$ then $\tau_3 = \dfrac{\lambda_3 \tau_1}{\lambda_1} \exp(-\alpha)$

12. A disadvantage of retrieving extinction profiles from micropulse lidar is that the lidar ratio S is unknown.

This statement is true. The lidar equation of MPL instrument has two unknowns: the backscatter and extinction profiles. Their ratio (the so-called Lidar ratio) has to be measured independently.

2. The aerosol optical thickness (AOT) has been measured at Ilorin (Nigeria) located at (8.32N, 4.33W) with a sunphotometer CIMEL at 500nm for a full year. In Nigeria, fuel wood burning is used for domestic purpose. This practice is constant all year long (same amount of AOT all year long). In Nigeria, they also burn the savannah every year during the dry season which extends from September to May fires in winter, spring and fall. The observed values of AOT (500nm) at Ilorin are: 0.8 (Dec-Jan-Feb), 0.55 (Mar-Apr-May), 0.35 (Jun-Jul-Aug), 0.45 (Sep-Oct-Nov).

Dust mass column is also known for two modes characterized by an effective radius of 0.75 um (fine dust) and 2.5 (coarse dust). The vertically integrated mass column, [g/m^2] for the two modes are: Fine dust 0.065163 (D-J-F), 0.061505 (M-A-M), 0.04902 (J-J-A), 0.055914 (S-O-N), and Coarse dust 0.5213 (D-J-F), 0.61505 (M-A-M), 0.78431 (J-J-A), 0.55914 (S-O-N).

Nigeria has very little industry and the observation site is situated several hundred miles inland, far from the ocean. We can thus assume that the only aerosol types present at Ilorin are dust, black carbon and organic carbon. From other data sources, we can reasonably assume that the mass column of organic carbon is 5 times the mass column of black carbon. Relative humidity at Ilorin is below the deliquescence point of any hygroscopic particles. Recalling that for constant aerosol properties with altitude, the optical thickness is given by the formula, $\tau = \dfrac{3Q_{ext}M_p}{4\rho_p r_{eff}}$, where Q_{ext} the extinction coefficient at 550nm (0.68 for organic carbon, 0.557 for black carbon, 2.7 for fine dust and 2.2 for coarse dust), ρ_p is the mass density (1.8 g/cm^3 for organic carbon, 1 g/cm^3 for black carbon, 2.6 g/cm^3 for both modes of dust), r_{eff} is the effective radius (0.087 μm for organic carbon, 0.04 μm for black carbon, 0.75 μm for fine dust, and 2.5 μm for coarse dust), and M_p is the vertically integrated mass concentration of aerosol type p.

Using the above information, we would like to know for the four seasons

1. What is the AOT (500nm) of dust,
2. What is the AOT (500nm) of carbonaceous aerosols from fuel wood burning (NB same value every season),
3. What is the AOT (500nm) of carbonaceous aerosols from savannah fires,
4. What is the mass column (in units of mg/m2) of black carbon from savannah fires.

Season	Question 1		Question 2	Question 3	Question 4
	Dust OT	Tot CC OT	Wood OT	Fires OT	BC mass
	(500nm)	(500nm)	(500nm)	(500nm)	[mg/m2]
DJF	2.0000E-01	6.0000E-01	1.0000E-01	5.0000E-01	1.8707E+01
MAM	2.2000E-01	3.3000E-01	1.0000E-01	2.3000E-01	8.6054E+00
JJA	2.5000E-01	1.0000E-01	1.0000E-01	0.0000E+00	0.0000E+00
SON	2.0000E-01	2.5000E-01	1.0000E-01	1.5000E-01	5.6122E+00